260
from the Author

THE WHIRLWIND THEORY OF STORMS.

BY DR. ROBERT HARE.

An effort to refute the whirlwind theory, or in other words to refute the opinion that in tornadoes and other travelling storms the whole of the air comprised within the theatre of stormy motion revolves about a common centre, while it is at the same time actuated by a progressive motion.

Various observations recorded by Redfield, seem to have established that certain storms, of that kind in which the winds blow in various and opposite directions, and which are consequently called hurricanes, commence in the Carribean Sea, travel first north-westerly towards the Gulf of Mexico, and then gradually bending their course into a north-easterly direction, proceed nearly parallel with the coast of the United States, percurring a distance of from fifteen hundred to two thousand miles, with a progressive velocity sometimes reaching to forty miles per hour.

I am willing to admit that there may be storms which correspond with this description. There is a great analogy between the progressive motion attributed to them, and that actually ascertained to be an attribute of tornadoes, which Mr. Redfield, justly, I believe, considers as hurricanes upon a comparatively small scale.

Nevertheless, agreeably to all that I have learned, tornadoes in the middle, northern, and eastern portions of the United States, travel from some point between north and west, to some point between south and east.

But however correct may be the allegations of Mr. Redfield respecting the existence of huricanes, of the description above given, it is certain that there are storms of another kind, to which this description is inapplicable.

Agreeably to the evidence collected by Loomis and Espy, there is a species of storm which, originating to the westward of the Mississippi,

travels from the north-west to the south-east until it goes out to sea. Storms of this description, as respects violence and blowing successively from different quarters at any one station, have all the attributes of a hurricane, and pursue a route similar to that above ascribed to tornadoes.

It is believed that, whether of the one kind or the other, hurricanes and tornadoes travel with the clouds which are instrumental in their generation. The clouds I conceive to perform the office of a coating to the electrified stratum of the atmosphere, between which and the subjacent terrestrial surface an electrical discharge taking place, causes a column of electrified air to ascend, repelled by the similarly electrified earth. Towards the area at the base of this ascending column, the air must flow in from opposite quarters, to restore the equilibrium of atmospheric density and pressure.

It is quite reasonable that the affluent currents thus produced, should gyrate, as water is seen to gyrate in a whirlpool; but in this case the gyration is a contingent consequence of the affluence of the opposite currents, and can only take place within an intermediate space towards which the opposite currents flow. As the intermediate space in the Loomis storm was not more than fifty miles in width; while in length it extended to two thousand miles, it was utterly impossible that the whole mass could revolve about a common axis. It appears that actually the winds were confined in their direction to two opposite quadrants, between north and west, and south and east.

It has been suggested to me by Prof. Henry, "that winds blowing from a higher to a lower latitude would by the earth's motion, as in the well known instance of the trades, be curved towards the west; while those blowing from the opposite quarter would be oppositely affected." To me it appears that this cause of gyration would be greater or less, or null, according to the amount of southing or northing accomplished within a given time by the winds.

The influence of this cause would lessen as the course of the storm should have in it less of northing and southing. In tornadoes the distance through which the currents move is too small for the cause in question to have a perceptible influence.

Moreover, the observations of Espy and Bache, and the observations respecting many storms collected and published by the former, are inconsistent with gyration being a usual attribute of storms.

I wish it to be understood, that I consider gyration in the atmosphere as quite consistent with laws of motion when considered as a secondary effect of centripetal currents; I only object to it when represented

as existing independently of such currents, and as extending throughout the whole area of the storm from the centre to the circumference. Evidently it is quite consistent that as a whirlpool is produced by water flowing inwards towards a descending column, so the air blowing inwards towards an ascending column should be productive of a whirlwind. But as a whirlpool can be sustained no longer than the momentum derived from the cause of influx endures, so is it with the whirlwind. *Inblowing* in the one case, is as necessary as *inflowing* in the other. Yet it would be an error to suppose that inflowing cannot take place without gyration. If any impediment be placed in the way of the whirl which may exist in a liquid running rapidly into a pipe, the whirl will be arrested, and will not be renewed although the impediment be removed. I have repeatedly realized this fact experimentally. Gyration is a contingent, not a necessary consequence of centripetal currents; unless some such cause as that suggested by Henry, influence the result, where winds blow over the terrestrial surface more or less in a meridianal direction.

With an exhibition of much science and assiduous sagacity, Espy has insisted that in tornadoes and travelling hurricanes the wind does not blow circuitously about a common travelling axis, but from opposite quarters towards an intermediate space or local area, over which the pressure has been diminished by the ascent of a column of air.

With Espy's view when restricted to tornadoes and hurricanes, I agree, *excepting as to the cause of the ascent of the air.*

It is by him assumed that this ascent arises from the expansion of the upper part of the column by the evolution of heat from condensing aqueous vapor.

Objecting to this cause as inadequate, agreeably to a reasoning elsewhere stated, I attribute the ascent of the air to a convective discharge of electricity between the earth and sky. The arguments by which I justify this view of the subject I shall postpone.

The theory which assumes the ascending column of air for its basis has been called the inblowing theory; that which supposes a general whirling in the whole aerial mass has been called the whirlwind theory.

The advocates of the latter rely upon observations obtained from the log-books of vessels at sea; but these are neutralized by the more reliable observations of Espy, Bache, and Loomis, made on terra firma. Being actuated simultaneously both by the progressive and gyratory velocities, the wind must blow in the most complicate cycloidal curves,

varying as one or the other of those velocities may be the greater, or as the observer may be more or less remote from the axis of the storm. Evidently it must be extremely difficult to show that the bearings recorded on the log-books of different vessels, are such as to harmonize with the fact that they are referable to the gyration of the same mass of air simultaneously travelling and revolving about its axis. On the other hand, it must be impossible for a navigator to infer, from the direction of a wind produced under such a complication of variable forces, his position in relation to the progressive direction of the storm, so as to know which way to escape from the violent portion as early as practicable.

Still more futile does it appear to undertake the instruction of a mariner so as to enable him to ascertain from the direction of the wind the position in which his ship may be placed relatively to the axis of any future storm, and thus to know how to avoid the more dangerous portion of the suppositious revolving aerial mass within which he may be involved. But while, from the complication of the supposed gyration with the progression of the storm, those observations which would prove it to be a whirlwind must be extremely questionable, other observations cited by the advocates of the whirlwind theory, are irreconcileable therewith ; so that it may be proved erroneous by facts adduced by its friends.

According to Redfield, a storm may have any diameter between three hundred and a thousand miles in extent. At three miles from the terrestrial surface, the air is only half as dense as at that surface ; we may assume three miles as the maximum of storm elevation. Imagine then a plate of air nine hundred miles wide, and three miles high, and of course having its altitude to its diameter as one to three hundred.

These proportions might be represented by an electrical plate of $\frac{1}{10}$ of an inch in thickness and 30 inches in diameter, or of $\frac{2}{10}$ of an inch in thickness and sixty inches or five feet wide, which would agree with those of the plate of a large electrical machine.

By what conceivable application of forces could such an aeriform mass be made to revolve, even if supported so as to move without friction. The glass disk, if supported without friction, would turn in obedience to any tangential force, because, in consequence of the coherence of its parts, the motion of one part involves that of the whole. Moreover, after being made to revolve, the consequent centrifugal force would be counteracted by the tenacity of its materials, but a similar impulse

would only push off a portion of the aerial plate, disturbing but little any portion which would be remote from the point of application.

To cause the whole aerial mass to revolve without derangement and so as to avoid diruption, every particle must be acted upon, at the same time, by velocities varying with the distance from the centre.

2. But the mass to be made to revolve existing as a part of the atmosphere, and there being no solid bodies in nature which can reach it, how can any cause of motion affect it without disturbing the circumambient quiescent air.

What is there to isolate it from that mass so as to induce in it separately a violent gyration?*

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* The only moving power suggested by Mr. Redfield is "*mechanical gravitation as connected with the rotary and orbitual motion of the earth.*" Admitting that these general forces could cause any portion of the atmosphere to rotate, it is inconceivable that the subjacent water of the ocean should not be similarly affected. Is it not incumbent upon the author of this idea, to show how the forces in question can be concentrated upon a particular disk of the atmosphere, so as to make it revolve within the surrounding non-revolving annulus of the same medium? "*Yet a rotative movement in the air*" is alleged by him to be "*the only cause of destructive winds and tempests.*"

For the generation of this rotative movement, the author combines with the general forces above mentioned the transient effect of obstructing bodies, as apparent in the following language.

The northern margin or parallels of the trade winds sweeping towards the Gulf, must necessarily come in collision with the archipelago of islands which skirt the Caribbean Sea. The obstruction which they afford produces a constant tendency to circular evolution.

These masses of atmosphere thus set into active revolution continue to sweep along the islands with increased rapidity of gyration, until they impinge upon the American coast.

Having thus given one of Mr. Redfield's explanations of the cause of his supposititious whirlwinds, I will proceed to give another, in which he loses sight of the planetary motions and the conflicting islands of the Caribbean Sea, and makes his whirlwinds a self-begotten progeny.

Agreeably to one of his expositions, it has been shown that every storm is due to "*a rotative movement in the air*" forgetting that as a rotative movement in the air is precisely the same thing as a whirlwind, this view of the subject makes a whirlwind a self-moving power.

The subjoined paragraph tends to confirm that view. "We observe that whirlwinds and spouts appear to commence gradually, acquire their full activity without the aid of any foreign causes; and it is well known that they are most frequent in those calm regions where apparently there are no currents to meet each other, and are less frequent where currents are in full activity."*

* *Silliman's Journal*, vol. xxxiii. p. 61.

But notwithstanding the failure of the advocates of the whirlwind theory to assign any adequate source of gyratory motion essential to them, let it be conceded that the whirling motion requisite to a hurricane has been communicated to a mass of air, of between three hundred and a thousand miles in diameter, and of an altitude not exceeding two miles,* I would inquire whether it would be possible that such a mass, while travelling as alleged at the rate of from twenty-five to forty miles per hour, could revolve about its axis when left to itself, without being soon retarded, and dissipating its momentum among surrounding portions of the atmosphere previously not participating in the whirl?

3. Is any result of the law of motion more thoroughly established, both in theory and practice, than that a whirling motion is transformed into a projectile motion in a right line, as soon as it ceases to be confined by a centripetal force, or some reaction which, like that of a string, is equivalent to a centripetal force? Is not this law verified in the case of a stone let loose from a sling, or the fragments of a fly-wheel or grindstone fractured during rapid rotation? In the case of fluids, is not the same law exemplified by the operation of the machine for winnowing grain, or of the rotary blowing machine now employed as a bellows? What then is to prevent the air in any whirlwind, not restrained by a centripetal force, from flying off in every direction? Is there anything which can prevent its dissipation, excepting the surrounding zone of air? But as action and reaction are equal and contrary,

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Is it conceivable that a disk or plate of air of from three hundred to a thousand miles in diameter, and less than three miles in height, may of its own accord assume a whirling motion, capable of producing the terrific violence of a hurricane?

The exclusion of all "*aid from foreign causes*" would seem to cut off all assistance from mechanical gravitation and from the rotary and orbitual motions represented as indispensable to storms, as already stated. In fact, the evidence here adduced by the author confutes his premises, which ascribe all winds and storms to planetary motion: agreeably to his own allegations, they may arise in an isolated aerial mass of the dimensions above cited, without any foreign aid, and of course without the influence of planetary motion; moreover, from the facts which he states, it must be evident that such motions can have no storm-producing influence on the isolated masses of air to which allusion has been made.

Again, the circumstances under which he represents storms to originate are such as to preclude the influence of any extraneous storm-producing agents. Their agency could not take place within a "calm region," without destroying the calm.

* It seems to me that gales do not extend higher than a mile. Mountains much less than a mile in height usually penetrate the clouds which bound the stormy stratum.

must not this zone be pressed outward, condensed, accumulated, and agitated, with a force equal to that centrifugal force which it counteracts, so that a rapid expenditure of the gyratory momentum must ensue?

Yet this is not, as I conceive, the sole cause of expenditure. It is well known, that, agreeably to a property of fluids experimentally illustrated by Venturi,* which has been designated as their "lateral action," one portion of a fluid cannot be made to flow through another portion at rest, without incessantly dividing its force with the filaments which come in contact with it; so that the mass throughout which the momentum is thus distributed increases incessantly as it proceeds. Meanwhile the totality of the momentum receiving no addition, the velocity must lessen as the actuated mass augments. It is in consequence of this property of currents, that a jet of steam, when projected through the air, associates with it so large a quantity of the aerial particles as to excite the combustion of coal or flame. The paradoxical phenomenon of the greater adherence of two disks the more violent the effort to separate them by a blast through a tube concentric with their common axis, also the exhaustion of a syphon by blowing through an associated tube, are evidently referable to the property of air under consideration.

Agreeably to an experiment of Venturi, (*Nicholson's Journal*, quarto series, vol. ii.) by a current of water projected through a vessel, with sufficient velocity to mount over the side opposite to that at which it enters, the vessel may be partially emptied of that liquid. But if this power which a current has to associate with it other portions of the fluid in which it takes place be great, when there is no unusual pressure, how much more active must be the growth of the mass actuated, when the current is impelled against the particles at rest, by a centrifugal force? Hence, is it not evident that were tornadoes to consist of masses of air whirling on their outside border, they would grow larger in diameter, and become less and less violent the longer their duration? Yet, actually, they retain nearly the same dimensions and activity for a great part of their course, and sometimes exercise greater violence as they proceed.

I presume that the preceding queries can only be so answered as to sanction the inference, that an enduring rotation in a mass of air cannot take place in consequenee of its *temporary* subjection to any forces competent to make it whirl, however rapid the motion at the outset. That

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* See Venturi's essay, *Nicholson's Journal*, quarto series, vol. ii.

there are in nature any forces capable of travelling with a whirling plate of air, of the dimensions above portrayed, as assumed to exist within the precincts of whirlwind storms, so called, has never, I believe, been advanced. The existence of such forces is to me utterly inconceivable, and the evidence adduced in the case of tornadoes is irreconcilable with their existence. By the author of the theory against which I am contending, we are informed that whirlwinds and waterspouts appear to commence gradually, and to acquire their full activity without the aid of any foreign cause; and that it is well known that they are most frequent in those calm regions where, apparently, there are no active currents to meet each other, and are the least frequent where such currents abound.

But it may be urged, that as little whirlwinds are often seen, it is evident that air may be made to whirl. I have already said that no cause can be assigned for the duration of such whirls, after escaping from the stationary eddy producing obstacles by which they are generated, unless we ascribe it to a deficit of pressure about the axis of the motion, causing a centripetal force by the effort of the air to restore the equilibrium in obedience to the hydrostatic influence of gravity. I infer that whenever any eddy, producing obstacle, or any other mechanical cause, has given rise to a whirl in a fluid, there is a greater or less deficiency of pressure caused about the axis by the generating force. Hence the whirl endures for a short time after the cessation of the mechanical force to which it owes its existence, at *first directly*, and *afterwards indirectly*, in consequence of the deficit created about the axis.

Thus there are two stages in the existence of the pigmy whirlwinds in question,—1st, that in which the rotary momentum is generated and accumulated; 2nd, that in which the accumulation thus made is expended. Evidently the sum of the force to be exhausted in the latter stage can never exceed that applied in the former. Now, whatever may be the velocity with which the generating forces are applied, it must follow that there is a certain difference of level, or of pressure, at which the contripetal force arising from the conservative hydrostatic influence of gravity will become competent to counteract the disturbing centrifugal force; and it is to me clear that this equilibrium of forces must take place as soon as the whirl reaches its greatest velocity.

In fact, where a storm is travelling, as those under consideration are represented to travel by the advocates of the whirlwind theory, the gyration* being produced, as by collision with any stationary body, an

* Gyration and whirling motion are used as synonymous.

island for instance, the application of the cause of gyration can be but transient, as the progression of the storm must soon cause the stationary obstacle to be left in its rear. But let it be admitted that there has been an application of forces competent to make an aerial mass revolve with any imaginable velocity, agreeably to the view above presented the difference of level, or of density adequate to compensate the centrifugal force, cannot exceed that which would result from a single gyration with a maximum velocity. Hence the secondary force, or that which could sustain the whirl after the aerial mass actuated escapes from the influence of the cause of gyration, will not exceed the force which it has derived from that cause, which, it has already been observed, cannot go beyond the power which one whirl, at a maximum velocity, is capable of producing. Precisely in proportion to the centrifugal influence of this whirl, and consequent diminution of pressure and density within it, will be the centripetal force consequent to the hydrostatic or pneumatic effort to restore the normal equilibrium of pressure and density.

It follows that there is nothing in the phenomena of pigmy whirlwinds which can account for a greater display of gyratory force than that which may have been caused during the conflict with the deflecting body produced. It has already been advanced, that any such conflict between a mass of air, travelling from 20 to 40 miles per hour, and a stationary body, must be of very brief endurance; and that the resulting gyration, admitting it to be thus produced, must be evanescent in consequence of the rapid expenditure of the gyratory momentum.

Evidently the store of momentum created by the diminution of density or depression of level, which sustains little whirlwinds and whirlpools must be wholly inadequate to perform a similar office in the case of enormous disks of atmospheric air necessary to constitute whirlwind storms. The smallness of the altitude, in proportion to the width of the masses in questions, is a feature of great disparity, and lessens much any analogy which might exist. And were it possible that a mass of air, of which the altitude should bear the same proportion to the width, as in small whirlwinds, should extend only six miles in height, the portion occupying the upper half of the containing space having consequently only one-fourth of the weight of the lower half, would create a feature of great incompatibility, from the diversity of momentum, and could not be fairly compared, as to its capability of uniform gyration, with comparatively minute masses, of which the upper and lower portions could not differ much in density.

Agreeably to the consideration above stated, I trust it will be admitted that no portion of a fluid mass, of which the parts are neither actuated by any centripetal force, nor confined by other portions of the same fluid, can revolve without being dissipated by the centrifugal force thence arising; and that if externally confined by other portions of the same fluid, the revolving portion must give off its momentum among the surrounding portions until it becomes evanescent.

The two stages of existence suggested, as respects the generation and endurance of pigmy whirlwinds, must of course arise in the case of whirlpools, originating in liquids from like causes. Those who have looked along the wake of a ship, sailing so swiftly on a tack as to require the frequent movement of the rudder, must have noticed that she leaves behind her a succession of little whirlpools. Each of these appears to originate in the following way: An occasional collision of the rudder with the water through which the ship is rapidly gliding, removes from the posterior space a portion of the fluid necessary to the level. The hydrostatic influence of gravity does not impel the water with sufficient force to enable it immediately to replenish the hiatus thus made; and there is a greater delay in the accomplishment of this result, since the liquid, being impelled towards the hiatus from every side, a conflict between the consequent centripetal currents ensues, which produces a whirl and a counteracting centrifugal force. Nevertheless, the whirl diminishes gradually in diameter, and soon ceases. It will be perceived that it is quite consistent that centripetal currents, meeting within a focal area should be productive of vortical gyration, quickening as the axis is approached.

Yet I trust it has been proved to be utterly impossible that any gyration in the whole stormy mass can display any of that violent motion immediately about the centre, which is admitted to take place in tornadoes and in hurricanes.

In addition to the objections above made to the possibility of an enduring gyratory motion being imparted to a mass of air, from three to a thousand miles in diameter, and of which the altitude cannot be more than a hundredth part of its width, its friction with the land, sea, and various rugosites and projections on the terrestrial and maritime surfaces, are to be considered. We can make a top spin upon its apex, but not upon its obtuse flat end. No one would undertake to make a cylindrical solid turn long on one of its bases, however smooth the supporting surface. As little would it be expected to cause it to revolve upon water durably, in obedience to any transient impulse, however

forcible. It does not materially alter the case, that the superincumbent disk should be a fluid. That waves are due to the friction which takes place between wind and water, is demonstrated by the fact that they are assuaged, when, by means of oil, that friction is prevented. Hence, it is evident that whatever motion the water acquires, is at the expense of the momentum of the wind.

If an estimate were made of the momentum requisite to produce all the waves created by a hurricane in travelling from the place of its nativity in the West Indies to the Banks of Newfoundland, it would, I think, much exceed any that could be imparted to an aeriform mass of the diametrical dimension assigned to whirlwind storms by their advocates.

In any whirlwind, travelling, as admitted, from 20 to 40 miles per hour, the velocity on one side must be at least thirty miles more; and on the other at least thirty miles less than the velocity on the limbs not affected by the progressive motion. Of course, if the mean gyratory velocity be eighty miles, the whole velocity on one side would be fifty miles, on the other one hundred and ten miles. Inevitably, the violence which conflicting bodies would experience, would be as the squares of these numbers, and, consequently, the expenditure of momentum would be nearly five times as great on the south-eastern limb as on the north-western limb.

When a solid, in rotating, meets with resistance in any part whatever, the result is imparted equally to the whole; but in a fluid, especially an elastic fluid, would not an inequality of density arise, inconsistent with durable gyration? Moreover, since the upper portions of the aerial whirling mass could not be directly subjected to this cause of retardation, would not a conflict inevitably ensue between the upper and lower portions, causing a loss of the rotary power?

It must be evident, from the opinions which I have expressed, that I should never have expected that in the scientific world the hypothesis in question could have received any countenance. But the fact has been otherwise, and efforts have been made to found, on the hypothesis, practical rules for escaping from the severer parts of storms, which, agreeably to my view, could only perplex and mislead.

In this point of view it will be admitted, that the question at issue has a high practical importance, and that the more flimsy the foundation on which the whirlwind theory has been erected, the more has it been important to give it a complete refutation.